



U.S. DEPARTMENT OF
ENERGY

Nuclear Energy

Fuel Cycle Waste Inventory

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**Actinide and Fission Product Partitioning and Transmutation
11th Information Exchange Meeting
San Francisco, CA
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Task Approach- FY10 Accomplishments

■ Multi Laboratory/Campaign Effort

- Joe Carter, SRNS
- Al Luptak, INL
- John Vienna, PNNL
- Robert Jones, SRNS
- Subject Matter Experts

Systems Analysis Transmutation Database

DOE Fuel Inventory Database

OCRWM Commercial Fuel Database

■ Inventory Task Treated as Data Calls

- Current inventory and future generation

■ Five Milestone Reports Completed

- FCRD-USED-2010-000031, Fuel Cycle Potential Waste Inventory for Disposition (Revisions 0, 1 and 2)
- FCRD-USED-2010-000033, Low Level Waste Disposition-Quantity and Inventory (Revisions 0 and 1)



DOE and Navy Used Nuclear Fuel

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■ Data Obtained from DOE-RW Yucca Mt. Project License Application

■ DOE UNF is Varied

- ~2,500 MT in Inventory ~50 MT of future generation expected, Isotopic Inventory Range 191 to 348 million curies

■ Navy Fuel

- ~65 MT in Inventory, Isotopic Inventory Provided for a Representative Naval Fuel Canister

■ HLW

- Based on the YM LA and Site System Plans
- Current Inventory
- Projected Inventory

	HLW Canisters ¹ (Best Estimate)	Yucca License Application Total Isotopic Inventory @2017 Millions of Curies
West Valley	275 actual	14.6
Hanford	9,611 - 14,111 (14,111)	134
INL (Calcine)	1,190 - 11,200 (3,328)	25.8
INL (Pyroprocessing)	82-135 (102)	
SRS	5,862 – 7,900 (6,300)	954

1. With the exception of Hanford all HLW canisters are 24 inches × 10 feet, Hanford HLW canisters are 24 inches × 15 feet



Commercial UNF Estimated Inventory Dec 2009

- **UNF Data thru April 2005 Obtained**
 - OCRWM Form 859 data thru Dec 2002
 - Updated thru April 2005
 - Data no longer compiled
- **Current Inventory Estimated at Dec 2009**
 - Nuclear Energy Institute (NEI) estimate method

Num of Assemblies			MTU			Average Initial Enrichment		Average Burnup	
PWR	BWR	Totals	PWR	BWR	Totals	PWR	BWR	PWR	BWR
94,713	124,043	218,756	41,067	22,128	63,195	3.72	3.07	39,322	32,698



Commercial UNF Future Generation

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■ No Replacement Nuclear Capacity

- Currently operating power plants (~100 GWe); One license extension to 60 years
- Fuel burn-up increases to extent allowed by a 5% enrichment (~54GWd/MT PWR)

■ Constant Nuclear Capacity (100 GWe)

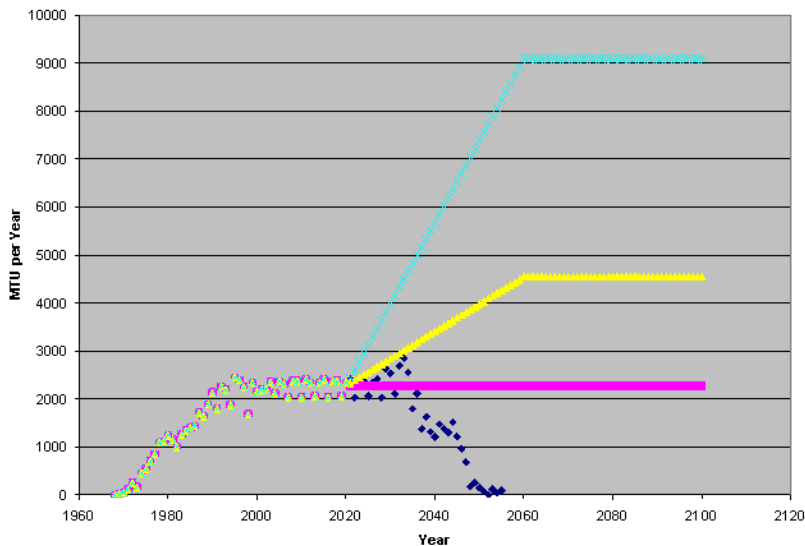
■ Increase to 200 GWe Capacity (Linearly between 2020 to 2060, then constant)

Assuming a 0.7% per year increase in electrical demand; the nuclear share is 15% in 2030

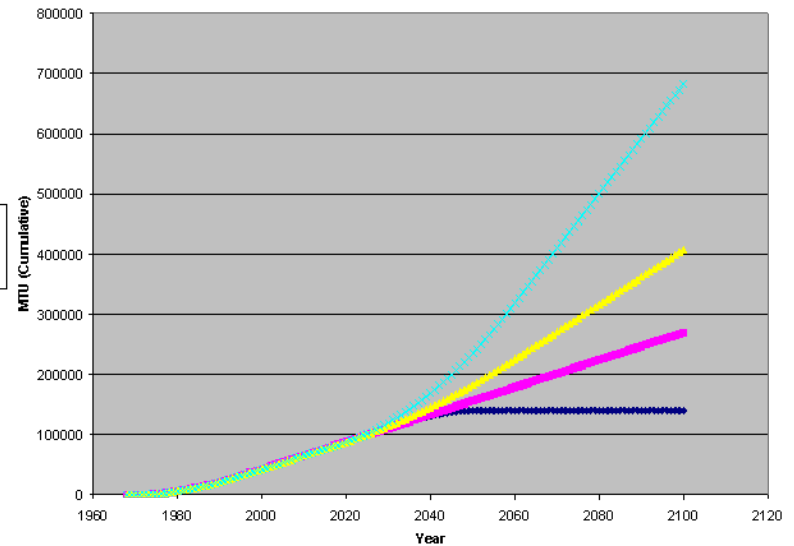
■ Increase to 400 GWe Capacity (Linearly between 2020 to 2060, then constant)

Assuming a 0.7% per year increase in electrical demand; the nuclear share is 30% in 2030

Graph of No Replacement, Maintain Current, 200 GWe, and 400 GWe Cases - MTU per Year -



Graph of No Replacement, Maintain Current, 200 GWe, and 400 GWe Cases - MTU Cumulative -



Commercial UNF Equivalent Reprocessing Waste Inventory

■ Mass, Volume, Containers and Decay Heat per Container Determined by using:

- 24 Representative LWR Fuels
 - *15 to 60 GWd/MT burn-up, 5 to 500 yr cooled, PWR and BWR*
- 4 Alternative Reprocessing Methods
 - *U/Pu single FP Waste form*
 - *Complete TRU recovery, single and multiple FP waste forms*
 - *Electrochemical*
- 13 Baseline Waste Forms
 - *4 for Captured off-gas*
 - *3 metal waste forms*
 - *6 FP waste forms*
- 9 Alternative Waste Forms
 - *4 for Captured Off-gas*
 - *5 for FP Waste forms*



Example- Borosilicate Glass

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		COEX			
		Borosilicate Glass			
		Containers: 2 ft diameter x 15 ft tall canisters. Each Canister Contains 2,900 kg.			
		Mass (kg/MT)	Volume (ft ³ /MT)	Containers per MT	Decay Heat (W/container)
Burn-up (GWd/MT) PWR 20 GWd/MT	Age (years)				
	5	198.53	3.22	0.07	14000
	30	147.61	2.40	0.05	7766
	100	147.61	2.40	0.05	3059
	500	147.61	2.40	0.05	1004
40 GWd/MT	5	410.33	6.66	0.14	14000
	30	268.66	4.36	0.09	8367
	100	268.66	4.36	0.09	2928
	500	268.66	4.36	0.09	884
60 GWd/MT	5	658.47	10.69	0.23	14000
	30	387.97	6.30	0.13	8667
	100	387.97	6.30	0.13	2546
	500	387.98	6.30	0.13	654

- Glass mass and volume is canister decay heat limited when short cooled fuel is processed regardless of burn-up
- Mass and volume is constant regardless of age once MoO₃ solubility limit is reached
- Additional Decay time will likely be required to meet repository heat limits regardless of fuel age at reprocessing (or waste loading must be reduced)
- Waste mass and Volume Increase with burn-up



Example- Borosilicate Glass

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		Fission Product Waste Summary															
		COEX				NUEX				UREX				UREX			
		Borosilicate Glass				Borosilicate Glass				Borosilicate Glass				Cs/Sr Ceramic			
		Containers: 2 ft diameter x 15 ft tall canisters. Each Canister Contains 2,900 kg.				Containers: 2 ft diameter x 15 ft tall canisters. Each Canister Contains 2,900 kg.				Containers: 2 ft diameter x 15 ft tall canisters. Each Canister Contains 2,900 kg.				Containers: 22cm diameter x 220cm tall canisters. Each Canister Contains 120 kg.			
		Mass (kg/MT)	Volume (ft ³ /MT)	Containers per MT	Decay Heat (W/container)	Mass (kg/MT)	Volume (ft ³ /MT)	Containers per MT	Decay Heat (W/container)	Mass (kg/MT)	Volume (ft ³ /MT)	Containers per MT	Decay Heat (W/container)	Mass (kg/MT)	Volume (ft ³ /MT)	Containers per MT	Decay Heat (W/container)
Burn-up (GWd/MT)	Age (years)																
PWR																	
20 GWD/MT																	
	5	198.53	3.22	0.07	14000	139.30	2.26	0.05	12124	116.84	1.90	0.04	4819	14.56	1.43	0.12	5697
	30	147.61	2.40	0.05	7766	139.30	2.26	0.05	2911	116.84	1.90	0.04	104	14.11	1.39	0.12	2572
	100	147.61	2.40	0.05	3059	139.30	2.26	0.05	562	116.84	1.90	0.04	7	13.64	1.34	0.11	515
	500	147.61	2.40	0.05	1004	139.30	2.26	0.05	0	116.85	1.90	0.04	0	13.52	1.33	0.11	0

- Recovery of Am/Cm by more complex processes reduces the decay heat such that the waste mass and volume is limited by the Mo solubility limit regardless of age
- More waste separation may allow minimization of a particular waste form (borosilicate glass) by re-directing some of the Mo (UDS) to another form (Metal alloy – not shown above) but will increase the total volume and mass to achieve another objective i.e. better waste form performance



■ Weapons Grade Pu MOX

- US and Russian Federation agreed to dispose of 34MT of WG Pu
- 1684 fuel assemblies
- ~77.8 MT of 50GWd/MT burn-up fuel is disposed
- Isotopics provided

■ MOX Fuel from Recycled LWR Pu

- Pu and U recovered from recycling 51GWd/MT, 5 year cooled LWR Fuel
- Each MT of LWR fuel reprocessed allows 108.9 kg of MOX fuel to be produced
- 50GWd/MT burn-up fuel is disposed
- Isotopics provided

Potential Waste from Recycling Advanced Burner Reactor Fuels

■ Mass, Volume, Containers and Decay Heat per Container Determined by using:

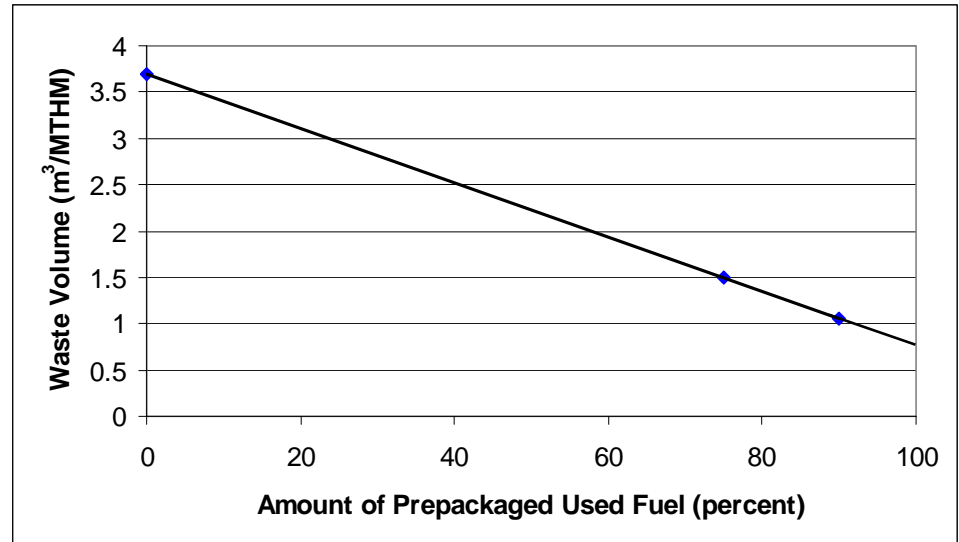
- 4 Representative LWR Fuels
 - *Reactor TRU Conversion Ratios of 0.5 and 0.75 for Oxide and Metal Based Fuels*
- 2 Alternative Reprocessing Methods
 - *Complete TRU recovery, single FP waste forms*
 - *Electrochemical*
- 9 Baseline Waste Forms
 - *4 for Captured off-gas*
 - *2 metal waste forms*
 - *3 FP waste forms*



Once-Through Fuel Cycle Secondary Waste Generation

Once-Through Fuel Cycle Wastes

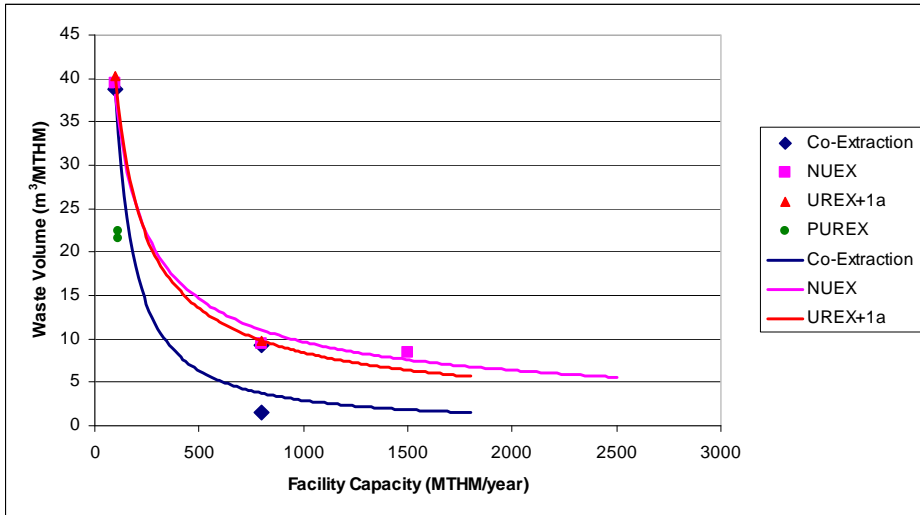
- **LLW generated from the disposal of used fuel (not from power reactor operations, not GTCC or mixed)**
- **Based on data obtained from the Yucca Mountain Draft Supplemental EIS (2007)**
- **Assuming 90% of used fuel is pre-packaged in dual-purpose canisters, LLW is generated at 1.06 m³/MTHM**
- **Sensitivity analysis:**



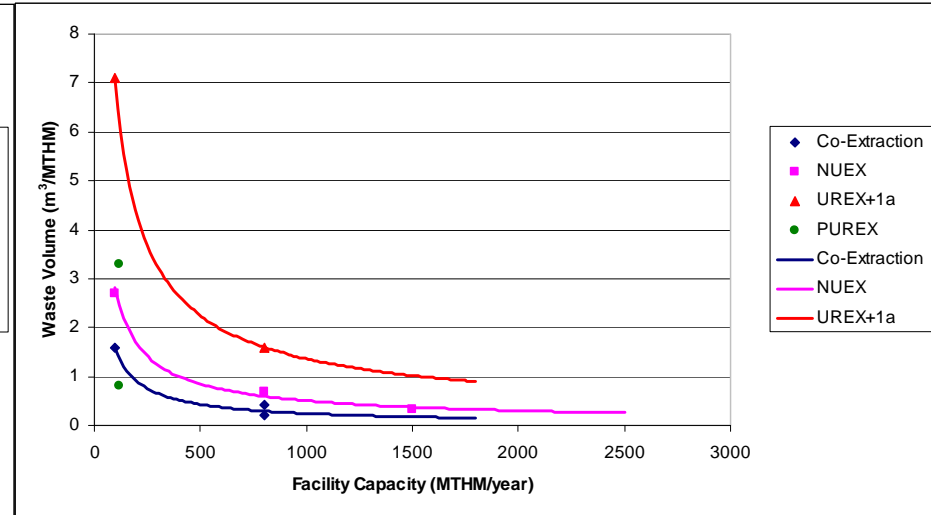
- Assuming 75% of used fuel is pre-packaged in dual-purpose canisters, LLW is generated at a rate of 1.5 m³/MTHM (Appendix A of Draft Supplemental EIS – elimination of one of three Canister Receipt and Closure Facilities and operation of one additional Wet Handling Facility)
- Assuming 0% prepackaging, LLW is generated at 3.7 m³/MTHM (elimination of remaining Canister Receipt and Closure Facilities and operation of five additional Wet Handling Facilities)



Potential Secondary Class A/B/C and GTCC Waste Volume from Aqueous LWR Recycling



Class A/B/C

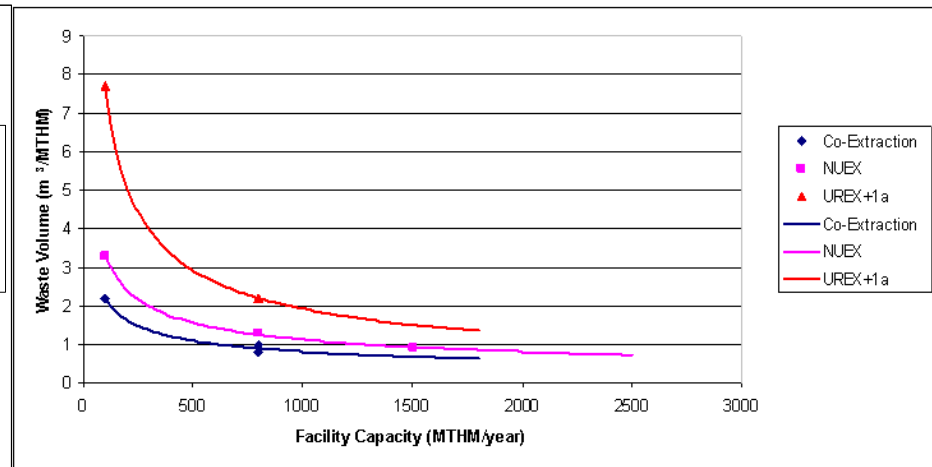
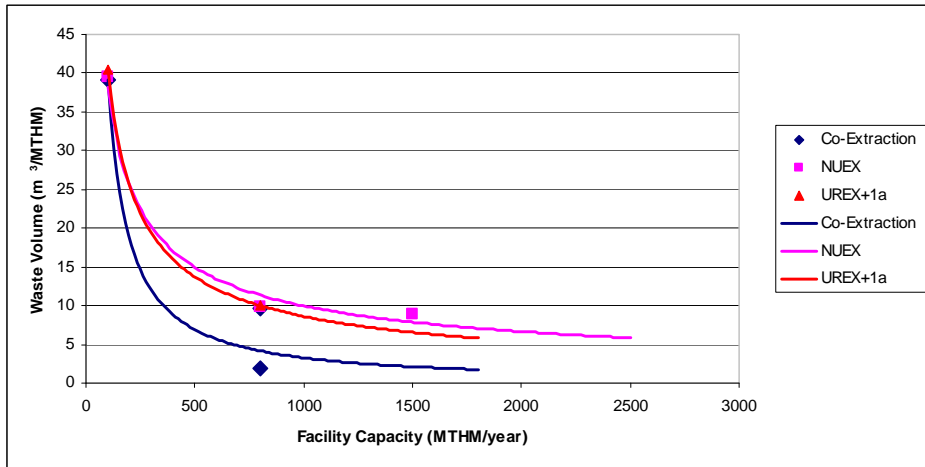


GTCC

- Based on data from AREVA (Co-extraction), EnergySolutions (NUEX), Engineering Alternative Studies (Co-Extraction, NUEX, UREX+1a, PUREX) and West Valley (PUREX)
- The reprocessing method has a significant affect on GTCC waste volume



Potential Secondary Class A/B/C Waste Volume from Aqueous SFR Recycling



Class A/B/C

GTCC

- Data derived from light water reactor used fuel recycling data
- Data shown is applicable to 131 and 166 GWD/MTHM burn up used sodium fast reactor used fuel
- GTCC Waste generation rates are slightly higher for 166 GWD/MTHM used fuel due to fuel design differences



Potential Secondary Waste Volume from Electrochemical Recycling

Light Water Reactor Used Fuel *

- LLW – 2,616 m³/ year (8.7 m³/MTHM **)
- GTCC – 919 m³/ year (3.1 m³/MTHM **)

Sodium Fast Reactor Used Fuel ***

- LLW – 2,716 m³/ year (9.1 m³/MTHM **)
- GTCC – 919 m³/ year (3.1 m³/MTHM **)

* Based on data from the Engineering Alternative Studies

** Based on a 300 MTHM/year recycling facility

*** Based on the LWR used fuel recycling data